# Development of GPR Techniques to Non-Invasively Measure Subsurface Water Content

Susan Hubbard, Katherine Grote[1] and Yoram Rubin[1]
[1]Dept. of Civil and Environmental Engineering, UC Berkeley
Contact: Susan Hubbard, 510/486-5266, sshubbard@lbl.gov

## RESEARCH OBJECTIVES

Water content information is vital for transportation, agriculture, vadose zone contaminant hydrogeology, global circulation models, soil erosion and geotechnical investigations. Subsurface water content is highly variable in both space and time. Conventional instruments for measuring soil moisture are not well-suited for collecting data over large areas since they require invasive drilling and sample only small volumes of soil. Currently, no technique is available to accurately provide soil water content measurements over the spatial and temporal scales necessary for estimating, monitoring and modeling subsurface moisture movement. In this project, we investigate the potential and limitations of ground penetrating radar (GPR) methods as a tool for providing accurate water content estimates in a non-invasive manner.

## APPROACH

We have conducted three field experiments to test the feasibility of using surface GPR to estimate subsurface moisture content. The first experiment was performed under very controlled conditions at a constructed "test pit" near Richmond, Calif., and the second was performed on two nearby engineered pavement sections. To test the method under more natural conditions, we have initiated a test at the Robert Mondavi Winery in Napa, Calif., where moisture content information is desired to dictate vineyard operations such as irrigation.

GPR methods use short pulses of high-frequency electromagnetic energy to probe the subsurface. Figure 1a shows an example of a GPR data display; this cube displays reflections emanating from soil layer interfaces that have different moisture contents or textures. This figure shows lateral changes in the soil stratigraphy (as indicated by the GPR reflectivity), and in moisture content (as indicated by the neutron probe measurements). As the travel time of the radar signal is primarily affected by changes in the moisture content in unsaturated materials, once calibrated, we can estimate moisture content of subsurface layers by analyzing the time it takes for an electromagnetic wave to propagate through the layers. An example from the test pit is shown in Figure 1b, where volumetric moisture content measurements, obtained in the laboratory using gravimetric techniques, are compared to estimates obtained using travel time information extracted from surface GPR data at one location in space. The difference between measured and GPR-estimated water content at the test pit is less than 1%.

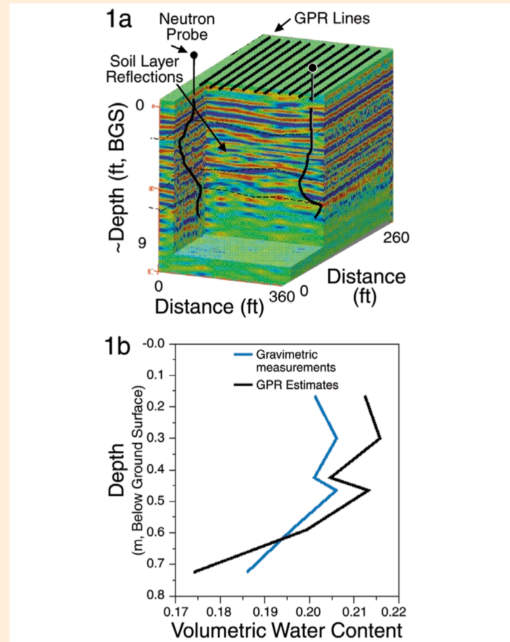


Figure 1. (a) GPR data display, and (b) comparison of GPR and gravimetric volumetric water content values vs. depth.

## ACCOMPLISHMENTS

To date, we have completed a proof of principle for the surface GPR technique at the test pit under very controlled conditions, developed a procedure to very precisely process the GPR data and extract travel time information, and worked on developing the petrophysical relationships needed to link the GPR travel time to moisture content. We are currently testing the potentials and limitations of this GPR method under variable saturation conditions at a pavement study site and in natural heterogeneous soils at the Napa field site. Once the GPR techniques are developed for use in the field, we will integrate the GPR information with remote sensing data collected at the Napa site. Our goal is to provide time-lapse, three-dimensional and high-resolution estimates of moisture content in a non-invasive manner.

## SIGNIFICANCE OF FINDINGS

Development of a tool that can quickly and accurately provide aerially extensive soil water content estimates in a non-invasive manner would be beneficial for many disciplines that require such information for their models or decision-making processes.

## RELATED PUBLICATION

Grote, K., S. Hubbard, A. Lawrence, J. Harvey, M. Riemer, J. Peterson and Y. Rubin, Nondestructive monitoring of sub-asphalt water content using surface ground penetrating radar techniques, EOS 80(46), PF291,1999.

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